DESIGN OF ROAD RIGID PAVEMENT AND COVERED CHANNEL DRAINAGE SYSTEM FOR FLOOD MITIGATION IN PHASE 3, MAIN ROAD, BRGY. FVR NORZAGARAY, BULACAN

A Research Project

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Bachelor of Science in Civil Engineering

Major in Construction Engineering

and Management

Benignos, Shaina Jane A.

Macalinao, Clarenze T.

Mancilla, Mary Joy

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RECOMMENDATION

This is to certify that this research entitled "DESIGN OF ROAD RIGID PAVEMENT AND COVERED CHANNEL DRAINAGE SYSTEM FOR FLOOD MITIGATION IN PHASE 3, MAIN ROAD, BRGY. FVR NORZAGARAY, BULACAN, prepared and submitted by Shaina Jane A. Benignos, Clarenze T. Macalinao & Mary Joy Mancilla have been examined and PASSED the PRE-ORAL DEFENSE.

ENGR. ELOISA P. CADAG, Reg. CE., MACT

Research Adviser

PANEL OF EXAMINERS

Examined and approved by the Panel of Examiners in a Pre-Oral Defense with a grade of _____ on November ___, 2025, at La Concepcion College, Bulacan.

Engr. Danilo A. Casas, LPT, MAEd

Chairman

Engr. Caroline A. Asuncion, MSCE, MPA — Member

Engr. Camilo A. Batulan JR., MSCM — Member

Accepted as partial fulfillment of the requirements for the degree of Bachelor of Science in Civil Engineering.

Engr. JORE GIL D. GALEZA
Division Head of Civil Engineering

LEILANIE I. CUSACK Ph.D, DBA
Division Head of Civil Engineering

CERTIFICATE OF ORIGINALITY

This certificate demonstrates the fact that the work was original to the researchers and that no other individual or group has written or published it before. Additionally, it declares that until proper acknowledgement has been given to them, no honors or recognition from other universities, colleges or higher education institutions were claimed here.

On top of that, we claim that our study's intellectual content is the product of our hard work, which required using both simple terminology and efficient presentation methods in addition to the group's original ideas.

Shaina Jane A. Benignos

Clarenze T. Macalinao

Mary Joy Mancilla

Attested by:

ENGR. ELOISA P. CADAG., REG. CE., MACT

Research Adviser

Date:

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ABSTRACT

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CHAPTER 1

The Problem and Its Background

Introduction

The Philippines is highly prone to tropical cyclones due to its geographical location, which consistently exposes the country to intense weather disturbances. These cyclones often bring heavy rainfall, widespread flooding, and powerful winds that severely impact infrastructure, agriculture, and human settlements. Flooding, in particular, ranks among the most destructive natural hazards in the country, causing extensive damage to lives, property, and the environment on a yearly basis (Glago, 2021).

Over time, rapid urbanization, poor waste management, deforestation, and inadequate drainage systems have diminished the land's natural capacity to absorb water, increasing the vulnerability of both urban and rural communities. Densely populated and low-lying areas are especially at risk, often lacking the infrastructure needed to handle heavy and prolonged rainfall. As climate change continues to intensify weather patterns, localized flooding is becoming more frequent and severe, pushing current flood control systems beyond their limits.

One area that is particularly vulnerable to flooding is the FVR Phase 3 main road, where both residential homes and local livelihoods are regularly affected. The topography of the area, marked by a steep incline, causes rainwater to rush downhill rapidly toward a nearby creek. While the creek forms a vital component of the local drainage system and ecosystem, it often becomes overwhelmed during periods of intense rainfall. As a result, the area experiences frequent and severe flooding.

The impact of this vulnerability was painfully felt during Typhoon Aghon on June 20, 2024, when floodwaters in FVR Phase 3 contributed to the loss of a life, highlighting the urgent need for improved flood management and infrastructure resilience in the community.

This study aims to design a drainage system for FVR Phase 3, Main Road, Norzagaray, Bulacan to help reduce problems related to flooding, accidents, and health issues affecting the residents. To address these concerns, we will conduct this research using modern methods and techniques such as topographic surveys, hydrologic and hydraulic analysis, and computer-aided design (CAD) tools. This study may also benefit other areas experiencing similar flooding problems.

Moreover, it will serve as a guide for future students and researchers by giving them ideas on how to address the same kind of problems.

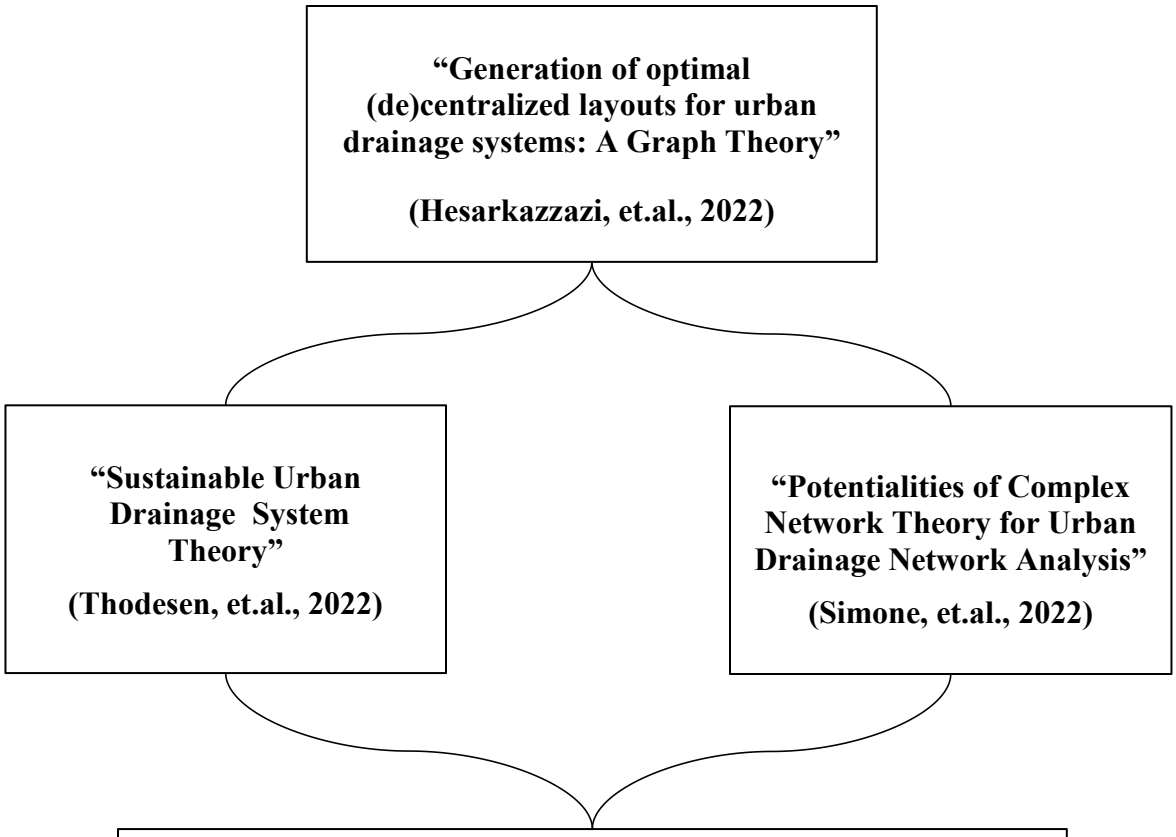
Background of the study

In recent years, we have been experiencing heavy rainfall in our country, and because of this, some areas have faced numerous problems, particularly flooding. Brgy. FVR, Norzagaray, Bulacan is one of the areas experiencing this kind of issue. Due to a poor drainage system and the area's steep elevation, rainwater rushes downhill rapidly toward a nearby creek.

At present, Brgy. FVR, Norzagaray, Bulacan does not have an efficient drainage system, causing rainwater to flow onto the roads. In addition, this further damages the roadway and increases maintenance costs within the community, particularly affecting the residents. Because of this, the existing drainage system cannot guarantee a long-term solution for the area. With this continuing problem, the lives of all residents in Brgy. FVR, Norzagaray, Bulacan have been put at risk over the past few years.

To address this concern, this study aims to design a road pavement and drainage system to provide an effective solution to reduce excessive flooding in the area. Furthermore, we will address these problems using modern methods and techniques such as topographic surveys, hydrologic and hydraulic analysis, and computer-aided design (CAD) tools.

Theoretical Framework


"Generation of optimal (de)centralized layouts for urban drainage systems: A Graph Theory"
(Hesarkazzazi, et.al., 2022)
"Sustainable Urban Drainage System Theory"
(Thodesen, et.al., 2022)
"Potentialities of Complex Network Theory for Urban Drainage Network Analysis"
(Simone, et.al., 2022)

We connect these theories to our study because they highlight the importance of proper drainage system design in urban areas. The Sustainable Urban Drainage System is an applicable solution for enhancing urban resilience and promoting environmental sustainability. Additionally, Graph Theory and Complex Network Theory support our study by helping identify and analyze data relevant to the design aspects. These mathematical models allow us to simulate and evaluate different design configurations in terms of efficiency and resilience. The focus of this study is to design a drainage system for Phase 3, Main Road, FVR Norzagaray, Bulacan.

Figure 1. *Theoretical framework illustrating theories from different studies.*

Conceptual Framework

INPUT	PROCESS	OUTPUT
1. What is the demographic profile of the respondents in terms of : 1.1 Age 1.2 Gender 1.3 Length of residency 2. How does a poor drainage system that causes flooding affect the lives of residents in Phase 3 FVR Norzagaray in terms of : 2.1 Vehicles and passengers safety 2.2 Source of water 2.1 Garbage segragation and disposal 3. How would the construction of road pavement and a proper drainage system provide benefits to residents, vehicles, and passersby?	1. Surveying 2. Statistical Treatment 3. Interview with Questioner 4. Cost Estimate	**1. N/A**

4. Is the installation of an outlet for the drainage system to the nearby creek at Phase 3 FVR Norzagaray sufficient to handle drainage water and prevent flooding based on the creek's maximum capacity?		

Statement of the Problem

This study aims to identify and analyze the key factors that must be considered in the design of a road rigid pavement and covered channel drainage system, which will be specifically addressed by the following questions:

1. What is the demographic profile of the respondents in terms of :
   - 1.1 Age
   - 1.2 Gender
   - 1.3 Length of residency
2. How does a poor drainage system that causes flooding affect the lives of residents in Phase 3 FVR Norzagaray in terms of :
   - 2.1 Vehicles and passengers safety
   - 2.2 Source of water
   - 2.3 Garbage segregation and disposal
3. How would the construction of road pavement and a proper drainage system provide benefits to residents, vehicles, and passersby?

4. Is the installation of an outlet for the drainage system to the nearby creek at Phase 3 FVR Norzagaray sufficient to handle drainage water and prevent flooding based on the creek's maximum capacity?

Objective of the Study

This research aims to provide a long-term solution to the infrastructure challenges in Phase 3, Main Road, Brgy. FVR, Norzagaray, Bulacan. It focuses on the design of an efficient drainage system and durable road pavement.

1. To conduct a survey in Brgy. FVR, Norzagaray to gather relevant information that will be used in designing the drainage system and road pavement.
2. To determine the exact materials and their types that will be used in designing the road pavement and drainage system.
3. To examine the types of soil before designing the road pavement and drainage system.
4. To determine whether this design is suitable for an area that often experiences the overflowing of water, which causes runoff.
5. To reduce the risk of accidents for residents, drivers, and students who regularly use the area.
6. To enhance the usability and comfort of the road, particularly during wet or slippery conditions.

7. To minimize hazards caused by inadequate drainage and road pavement conditions.

Hypothesis

Ha: The design of the road drainage system would not have a significant impact on the residents in Phase 3 FVR, Norzagaray.

Ho: The design of the road drainage system would have a significant impact on the residents in Phase 3 FVR, Norzagaray.

Significance of the Study

This study is important to several people as it focuses on the design of drainage system and road pavement in Phase 3, Brgy. FVR, Norzagaray, Bulacan. The findings of this study will benefit the following:

For Future Researchers - This research study will serve as a useful reference and source of guidance for future researchers, providing them with knowledge and insight, particularly on road pavement and drainage systems on how to address similar problems in the future, especially in areas where such issues are neglected by the government, such as in remote or under-served communities.

For Local Residents - The results of this study may contribute to the improvement of drainage systems and road pavements by providing effective solutions in Phase 3, Main Road, Brgy. FVR, Norzagaray, Bulacan. This may help make these infrastructures more accessible, efficient, and sustainable, while also raising public awareness among residents about the impact of these issues on their daily lives, especially during bad weather.

For Local Government - The results of this study will help government agencies identify and better understand the current situation of the barangay, particularly regarding issues related to road pavement and drainage systems. This information can support data-driven decision-making and assist in the prioritization of infrastructure projects. Furthermore, the outcomes of the research can help reduce the workload of the government by promoting more efficient planning.

For the School and Professor/Instructor - This research contributes importantly to the academic field of civil engineering that combines structural design with environmental management. It gives the educators a relatable, real world case study to enhance their teaching of engineering principles, showing the students how these ideas are actually used in real projects. Also it encourages the students to apply academic knowledge to community based challenges, social responsibility, and sustainable development in future engineering practices.

Scope and Limitation

This project presents the engineering design for a durable concrete road and a drainage system along the main road of Phase 3 in FVR Norzagaray, Bulacan. The project aims to find solutions for the persistent flooding issues affecting the area.

It's important to clarify that this study only focuses on the design of road pavement and concrete channel covered alongside the road. The information used in the design process is sourced from pre-existing topographic, rainfall, and soil data. It should be noted that this data may not completely account for potential changes that can be used in the future climate scenarios or urban expansion. Additionally, the study is strictly limited to the designated section of Phase 3, excluding nearby roads and other surrounding areas.

Definition of Terms

The following terms are theoretically defined for better understanding of the present research study.

Concrete drainage channel - is a system which allows the flow of water from one location to another.

Rigid Pavement - also known as concrete pavements, are a type of road or pavement structure that provides a durable and long-lasting surface for vehicular traffic.

Flood mitigation - reduces the overall risk of structure experiencing flood damage, and also reduces the severity of flood damage when it occurs.

Storm Drainage - channels and underground pipes that carry or even a small amount of water waste.

Low lying Areas - lying below the usual elevation or altitude.

Runoff - water from rain or melting snow, or liquid from an industrial or farming process, that flows into a place such as a river.

Digital Elevation Model (DEM) - is a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects.

The Storm Water Management Model (SWMM) - is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas.

Heavy Vehicle Simulator (HVS) - is an accelerated, full-scale loading facility that accelerates pavement failure by simulating many years of traffic loading in a few months.

CHAPTER 2

Review of Related Literature

This chapter presents the relevant literature and studies reviewed by the researcher to highlight the significance of the present study. It also includes a synthesis of related works to provide a comprehensive understanding of the study.

Foreign Literature

As per "Efficient Design of Road Drainage Systems" by Aranda, et al., (2021), the article is based on the idea of the public health implications of drainage systems, explaining how these systems collect debris and waste materials resulting in the obstruction of water flow that can prolong the flow of water that is already caused by excessive storms, and thus, facilitate the distribution of microbes and contaminated water into houses and city environments. It is further elaborated that during rain, the rubbish gets mixed with the rainwater, forming ideal breeding grounds for pathogens that may cause gastrointestinal tract, skin, and mucus membranes infections; children and communities with less sanitation facilities get infected the most; the effect becomes more intense when clean-up is difficult and the way to healthcare is far. Moreover, every bit of debris taken from the system also pollutes rivers with plastics and chemicals, which, in turn, may cause damage to fish health and to people who use the water for drinking. In short, it communicates the need for a citizen education program on littering, plus a consistent cleaning of city drainage systems to lessen some of the health risks related to rains and storm surges.

The study indicates that regular maintenance, public education on littering, and improved design strategies that incorporate waste management and hydraulic efficiency to prevent pathogen breeding and environmental pollution may be the concrete solution to the problem of drainage systems accumulating debris and waste, which leads to prolonged water flow during storms and spreads microbes and contaminated water into urban areas—disproportionately affecting vulnerable populations like children and those with limited sanitation access.

Finally, the study highlights that incorporating cleaning and community education into drainage system designs not only leads to the direct reduction of health risks from contaminated water and pathogens, but also to overall environmental sustainability, which was the essence of the summary. By focusing on the preventive measures, it helps public health from flood-prone areas, the least impact on ecosystems, and long-term urban resilience to storm-related hazards are the benefits realized.

An instance to refer to is the "A Review - Design of Drainage Systems in Highway Construction" by Ramawatar & Matute (2023), where the background of the paper conveys the difficulties faced in planning such a drainage system for roads and transport as mentioned in the given data. Ramawatar and Mature point out that it is not an easy task to make the correct drainage for roads and transport on the planning side. No matter what the place is, the rain, topography, and even rules

might be different. Countries such as the US install big pipes and pumps to get rid of water on roads quickly. These methods avoid flooding, which is a main reason for getting cut off from the outside world, so people will not lack food or help during the time that the flood lasts for days.

A glimpse of the literature is the problem of under performing drainage systems in highway constructions, which, because of diverse rain patterns, land features, and regulations, may cause flooding and isolation of communities that can be solved efficiently through methods such as employing huge pipes and pumps to evacuate water from roads promptly, similar to the solutions adopted by nations like the US, thereby averting creek overflows and ensuring accessibility during floods.

Finally, the literature highlights that using a combination of local conditions-based customized drainage designs and the latest technology can make a big difference in the highway's ability to withstand, minimize the effects of flood, and help keep the community safe, as suggested in the data, thus moving forward the much-needed infrastructure planning that facilitates sustainable transport networks.

Article titled "Evaluation of Concrete-Lined Drainage Systems for Roadside Erosion Control and Hydraulic Efficiency," by Kumar et al., (2023) from Civil Engineering Journal, Volume 17, 2023 provides a comprehensive account of the implementation of concrete covered drainage in the field of roadside applications.

The study refers to the difficulties of managing the storm-waters in city and highway areas that have been increasing. There, the usually used earthen or vegetated drainage systems fail most of the time due to the occurrence of erosion, sedimentation, and insufficient hydraulic capacity. Research points out that the trend of switching to concrete-lined drainage systems to solve these problems has been noticed since the beginning of the 21st century. The latter systems produce durability and resistance to wear that come from vehicles and weather besides the rest of the advantages. The study uses data collected from roadside places in India to show how concrete coverings raise the flow rates of water and soil loss gets lower. Few research works presenting experiments are mentioned here to refer to the performance of drainage better by 30-40% as compared to that of unprotected channels, which is directly quoted from the methodology and results sections of the paper.

The findings of the study propose that the main issue with roadside drainage that the lack of protection leads to the rapid decay of the systems and consequently to flooding, road damage, and environmental pollution might be solved satisfactorily by the use of designs covered with concrete. As the text explains, concrete linings are the source of erosion-free water flow since they give a smooth and impermeable surface that ensures minimum sediment buildup and facilitates water conveyance. Other than that, it also mentions the use of reinforced joints as a feature that can withstand heavy loads from vehicles. The researchers substantiate their simulations and case studies with numbers that show how these systems help in achieving

savings of maintenance costs by 25% for a 10-year period and additionally contribute to hydrological performance in areas of heavy precipitation, as evidenced by the parameters of flow velocity and capacity investigated by the authors.

At last, the research work points to the fact that concrete-covered drainage systems will be safe and economical options for the use of the roadside, as they are based on the results of long-term tests that give positive evidence of endurance with a minimum of wear out. The authors suggest more considerable installation potential, especially in the third world, together with the implementation of a comprehensive design immediately to enjoy maximum benefits as well as to cope with the consequent environmental problems such as the falling of groundwater recharge as can be implied from the article's concluding remarks and suggestions. This fact, along with the resultant increased safety and sustainability, shows the importance of such integration into infrastructure planning.

In the literature titled "A Review of Nature-Based Infrastructures and Their Effectiveness for Urban Flood Risk Mitigation" by (Esraz-Ul-Zannat et. al 2024), the literature background identifies how the local piped drainage systems beside the roads, creeks, and streets that are outdated and in poor condition are not sufficiently handling the overflow caused by rain during extreme storms, as the provided information has indicated. Consequently, these old sewage systems cannot remove the excess water from roads leading to the flooding of streets and slippery walkways, which in turn increases the possibility of occurrence of car crashes — the research

results specify that the number of accidents can be doubled on wet tracks as a result of the driver's losing the control of the vehicle. Apart from that, these installations were constructed with the purpose of accommodating a lighter amount of rain, but they are already dying under urbanization's pressure, as more asphalt and concrete pave the way for rainwater, which is flowing into the drains in larger quantities than before, leaving the roads to be transformed into flooded rivers that are speeding up the erosion of the lowest parts of the land that were already prone to flooding; all these phenomena are causing an interruption in both the flow of traffic and the people's lives in the era of climate change.

The Article argues that the situation of deteriorated piped drainage systems that lead to streets being flooded is quite problematic as these systems have been designed to handle maximum rains but have failed to do so, thus flooding the streets, and as a result of the flooding crash risks and erosion issues arise as well. The text describes the solution as "a redesign and update of the systems approach with a major focus on green infrastructure and land-use converted spaces to not only allow the runoff to percolate naturally but also maintain safety on the roadways and reduce surface flow during extreme rain events." The paper suggests that this issue of dilapidated piped drainage systems unable to manage excess rainwater during stronger storms, resulting in flooded streets, increased crash risks, and erosion in urban areas,can be solved by a plan involving the update and redesign of these systems—with particular attention to green infrastructure and land-use spaces not

only for allowing runoff to percolate naturally but also for maintaining roadway safety and reducing surface flow during excessive rainfall events.

Basically, the article keeps on saying that by integrating these modern drainage designs with nature-inspired solutions, the flooding issue along with other safety concerns could be resolved immediately, and furthermore these measures would be a good insurance against climate change in the long run as per the main points in the summary section. The urban planning is advanced with the help of nature-based solutions, which are known for their sustainability feature and can make cities more resilient to the potential disruptions from the daily lives of people and also can significantly fill in the considerable research gaps in flood risk management. All in all, this research is instrumental to the achievement of the efficient and effective infrastructural development of the cities that are growing in population and likewise making them safer and more adaptable to future changes.

Based on the article "Assessing Surface Water Flood Mitigation Strategies: A Global Comparative Review" by Rotimi et al., (2024), outlines the benefits of advanced flood management strategies, as indicated in the given data. Rotimi mentions that these advantages result from ingenious designs which very quickly divert water, thus turning flood areas into the most dependable routes that can facilitate the general health of the community and the rapid arrival of emergency services.

One such solution that the study points out can resolve the problem of surface water flooding in urban areas leading to community health risks and emergency access issues is employing smart design strategies that accomplish the task of water diversion in a prompt manner which in turn makes the flood zones safe, reliable pathways for better public health and quicker response times during floods.

To sum up, the study underlines that putting into practice these resourceful flood mitigation concepts indeed strengthens community resilience and health, thus improving overall urban planning as mentioned in the data which is a step towards establishing safer environments and more effective emergency operations in the scenario of elevated flood risks.

Local Literature

Bañados and Quijano (2022) released an article titled "Rainwater Retention Site Assessment for Urban Flood Risk Reduction and Flood Defence in Mandaue City , Philippines". According to them, they used a geospatial technique to locate ideal sites for rainwater retention zones in Mandaue metropolis, a heavily populated metropolis in Cebu, Philippines. To redirect surface water runoff from flooding streets and hindering traffic, optimal rainwater retention sites were created using remote sensing and Geographic Information System (GIS) integration. Ideally, the chosen sites should have a limited infiltration capacity and be in open areas. We evaluated the amount of surface runoff, elevation, soil characteristics, land use, and

the research area's current drainage status when preparing the study's hydrology. The slope raster is obtained using a Digital Elevation Model (DEM) developed using LiDAR technology. Small streams are generated. Surface runoff was calculated based on the area's land cover and curve number (CN). The soil textures were modified according to their penetration rate and runoff potential. Finally, the weighted overlay tool in GIS generated a layer suggesting probable rainwater retention sites. The data show that 54.8% of the research area was suitable for water collection, with open land regions accounting for 2.3% of the best spots. Furthermore, the majority of acceptable areas are on clay loam soils and range in elevation from 0 to 25 meters. These findings will greatly assist policymakers and urban planners in developing solutions to the city's flooding problem and the impending water catastrophe.

Based on the article published by Contreras et al., (2023) Flooding is a problem that demands immediate action because it puts at risk the public's health and safety, damages homes and businesses, and disrupts transportation and other essential services. Flooding can have a number of detrimental effects on people's physical and mental health. Populations living in flood-prone areas may endure repeated flooding occurrences, as the frequency and intensity of flooding events are expected to increase in the future. It is one of the most devastating natural catastrophes to strike the Philippines. San Guillermo Village, located in Barangay Tinajero, Bacolor, Pampanga, has repeatedly experienced catastrophic flooding. As a result, establishing a realistic remedy that would relieve the affected inhabitants from

the terrible repercussions of such flooding is critical, as is examining the elements that contribute to flooding in the studied region. The hydraulic performance of the existing storm drainage system design was evaluated using Manning's equation and the Rational Method, and a suitable drainage system design was provided, which included the installation of adequately sized pipes to increase system performance. Furthermore, this study advised appropriate ways to alleviate the consequences of floods in the area, such as the installation of a cistern tank equipped with a pumping system. A more precise calculation of the cistern tank's capacity and size was also performed to ensure efficient water storage and utilization. Overall, these proposals seek to address the issue of flooding in the study region and provide effective and long-term solutions for the benefit of the affected inhabitants.

According to the article of Castro et al., (2023), the Philippines' urbanization transformed natural areas into impermeable surfaces, contributing to the contamination of surface runoff and surrounding water bodies. Low Impact Development (LID) technologies were offered as a replacement for traditional drainage methods, specifically permeable pavements. Such technology is excellent for reducing stormwater runoff, enabling ground infiltration, and treating stormwater. This study looked into the feasibility of permeable pavement for sustainable stormwater management in a university context, namely at De La Salle University - Laguna Campus. The Storm Water Management Model (SWMM) was used to simulate various rainfall scenarios in chosen areas with little to no vegetation and increasing permeable pavement area coverage. The results revealed that the LID

surface area to subcatchment area (SA/CA) ratio is inversely proportionate to the total runoff reduction seen across all rainfall scenarios. When the SA/CA ratio was at least 50%, total runoff fell to zero. The permeable pavement was found to be successful in surface runoff infiltration, reduction, and storage, making it useful for long-term stormwater management and flood protection measures. The findings can be applied in future research and applications involving comparable LID technologies.

According to the article by Palcis (2024) entitled “Integrating Sustainable Urban Drainage Systems (SUDS) for Enhanced Urban Resilience and Environmental Sustainability in the Philippines,” he said that the Philippines' rapid urbanization has caused urban drainage difficulties, resulting in increased flooding, water pollution, and environmental damage. Traditional drainage methods are frequently ineffective in resolving these difficulties, suggesting that there must be more sustainable solutions. This study investigates the use of Sustainable Urban Drainage Systems (SUDS) as a possible approach to improve urban resilience and environmental sustainability in the Philippines. The study examines the current state of urban drainage systems in the country and identifies the benefits and feasibility of implementing SUDS using a comprehensive analysis of existing literature, worldwide case studies, and local data. The key findings show that SUDS, which comprise permeable pavements, green roofs, and rain gardens, may greatly improve water management, minimize flood risks, and improve urban aesthetics. The report presents a strategy framework for SUDS integration that includes policy suggestions,

design standards, and monitoring methodologies. Urban planners, politicians, and stakeholders can use this framework to implement SUDS and create more resilient and environmentally sustainable urban environments. The study concludes with recommendations for further research and emphasizes the potential of SUDS to address important urban drainage issues in the Philippines.

Based on the article published by Cabanesas et al., (2025), flooding induced by creek overflows poses substantial threats to communities, especially in flood-prone locations with poor drainage systems. This study analyzes the discharge capacity of Labni Creek in Brgy. Las Piñas, Peñaranda, Nueva Ecija. The goal is to identify effective engineering improvements for flood prevention. Site inspections and hydraulic study found that the existing reinforced concrete pipe culvert is insufficient, with a discharge capacity of only 3.78 cubic meters per second, as opposed to the creek's highest discharge of 89.8 cubic meters per second. The study also highlighted sediment accumulation, limited vegetation, and a lack of flood control facilities as major causes to overflow. Alternative structural solutions were analyzed using Manning's and Rational Formulas, and the two-barrel box culvert was found to be the most effective. This proposed structure meets AASHTO and DPWH standards, resulting in better water flow management and lower flood hazards. The findings emphasize the importance of urgent intervention, such as dredging, vegetation management, and improved culvert design, to strengthen the creek's resilience and protect nearby populations from recurring flooding.

Foreign Study

According to the "Efficient Design of Road Drainage Systems" study by Aranda et al. (2021), restoring the natural drainage network and removing excess surface water (waterlogging) are two of the main issues in stormwater drainage design for roads and transportation infrastructure. Rainwater build up on roadways can make driving dangerous by impairing sight and decreasing tire-to-pavement friction. Government agencies in charge of highway and road planning frequently release design standards or guidelines to guarantee safe driving conditions during rainy events in order to reduce these risks (e.g., M.O.P.U. in Spain, Brown et al. (2013) in the USA, and the Department of Energy and Water Supply in Queensland, Australia).

Usually, the main goal of these regulations is to direct rainwater from roads into side gutters. Typically, the design of these gutters uses simplified uniform flow equations to limit the spread of surface flow. After being collected in the gutters, water is transferred into subterranean drainage systems via a variety of inlets, the placement of which is advised. The official papers from the USA, Queensland, and Spain describe the kinds of gutters that are allowed, the right lining materials, and how gutters should be positioned according to the slope of embankments and road cuts. Every document stresses the necessity of confirming gutter performance for the design discharge under consistent flow circumstances, and some explicitly outline the necessary flow characteristics in the system.

Based on the study of Monachese et al. (2024) titled “Challenges and Innovations in Urban Drainage Systems: Sustainable Drainage Systems Focus” Urban drainage networks are important for protecting cities from the consequences of bad weather, especially as climate change makes rainfall patterns less predictable. Floods are happening more and more. over the world, and they are bad for the environment and cost a lot of money. Urban areas are more likely to flood because of changes in natural water flow and changes to the ground caused by people. If the amount of water exceeds the network's specified capacity, flooding can happen when heavy rains overwhelm drainage systems.

To solve these problems, Sustainable Urban Drainage Systems (SuDS) were designed to control stormwater flow and keep infrastructure and populations safe from bad weather. The academic literature is giving SuDS more and more credit, with several studies stressing how important they are for modern urban planning.

To get the right size for SuDS parts, designers normally figure out how much water will flow off the ground during heavy rain. This means using hydraulic modeling techniques, intensity-duration-frequency (IDF) curves, and looking at past rainfall data. Ferrans et al. (2022), Karami et al. (2022), and Viavattene & Ellis (2013) have all looked at how these design methods are used in real life.

Many studies have shown that SuDS can help meet crucial hydrological goals. Research by D'Ambrosio et al. (2022) and Guptha et al. (2022) shows that SuDS can help reduce flooding in cities. Almaaitah et al. (2021) say that SuDS are an important

aspect of strategies to deal with climate change since they ease the stress on traditional sewer systems.

In the research conducted by Anvigh et al. (2024) titled “Designing Sustainable Drainage Systems as a Tool to Deal with Heavy Rainfall—Case Study of Urmia City, Iran” This study outlines three alternative options for addressing stormwater flow issues in urban areas. The first scenario is about making the current stormwater drainage system better by making it longer. This would include putting in more runoff channels or ditch raceways on both sides of the street, since some streets only have drainage on one side. The goal is to make the system better at handling and moving stormwater. The second scenario uses a low-impact development (LID) method by adding permeable pavements to main roads. The goal of this method is to lower surface runoff by using infiltration and surface absorption. Prior studies have shown that permeable pavements can effectively reduce the amount of runoff. In the third scenario, vegetative swales are used as part of a LID approach. These planted conduits would send runoff to green areas with trees and plants along the street. This approach would not only cut down on runoff, but it would also make the city seem better.

The study suggests three ways to better manage stormwater in cities: adding to the current drainage system, using permeable pavement technologies, and adding vegetative swales. Simulated evaluations of these situations establish a basis for discerning the most effective and sustainable methods for urban water management.

Based on the study of Hoang et al., (2024) entitled “Assessing the impacts of urbanization and climate change on urban drainage systems” Flooding in cities is one of the big problems that many cities are working to solve in order to make sure that development is sustainable. Engineers have often employed the traditional method of upgrading drainage systems to lower the risk of flooding. Due to climate change and urbanization, stormwater management systems may not be able to handle the overflow that they create, which leads to severe flooding in many places across the world.

This study examines the impact of climate change and urbanization on urban flooding by utilizing the EPA Stormwater Management Model to simulate drainage systems within an urban watershed. The findings indicated that urbanization diminishes the initial abstraction capacity, whereas climate change exacerbates extreme precipitation and elevates the water levels of receiving sources. The effects are significantly worse when the pace of urbanization rises by more than 70%, together with climate change.Consequently, this study seeks to examine the possible impacts of climate change and urbanization. It will specifically concentrate on elucidating the impacts of climate change on the potential rise in rainfall frequency within the region. Simultaneously, it examines the impact of urbanization on flow formation in metropolitan regions, which is crucial for assessing flood risk and establishing a robust foundation for climate change adaptation and the subsequent modification and enhancement of planning strategies.

The study of Pachouri et.al., (2025) titled “Revolutionizing Urban Water Resilience: Innovative Strategies and Advancements in Sustainable Urban Drainage Systems (SuDS).” The Sustainable Urban Drainage Systems (SuDS) use natural processes including infiltration, evapotranspiration, and pollution filtering to control stormwater right where it starts. This method helps the ecosystem around it and makes the water cleaner. SuDS make flooding less damaging, lower long-term maintenance costs, and can raise property values by adding attractive, useful green spaces.

The study emphasizes the need to integrate SuDS into urban planning strategies to address challenges related to climate change, rapid urbanization, and increasing infrastructure demands. Beyond their functional role, SuDS offer added benefits such as flood risk reduction, climate resilience, and improved community well-being. Their implementation also supports several of the United Nations Sustainable Development Goals (SDGs), including clean water access, sustainable urban development, and climate action. Therefore, policymakers are encouraged to align SuDS with zoning regulations, promote investments in the commercial sector, and require new developments to adopt sustainable stormwater practices. Furthermore, SuDS should be integrated with other sustainable urban design elements like energy-efficient buildings and eco-friendly transport systems to help create adaptable and climate-resilient cities.

Local Study

Based on the study of Teruel et al., (2021) titled “Improving Drainage System in Brgy. Bamban And Brgy. Sto. Rosario” Excess water must be removed from a property's surface or root area using a drainage system. Drainage systems eliminate excess water, allowing the soil to warm more quickly in the spring. In contrast, a system that cannot release incoming water into a major river, sea, or other body of water as quickly as it receives it is said to have poor drainage, which causes overflow and floods in streets and Roads.

A comprehensive understanding of the mechanics of water transport in roadways is crucial for several reasons. Road engineers, geotechnical engineers, and environmental scientists are three practitioner groups that are naturally interested in moisture-related concerns. It is commonly known that the rate of road deterioration rises with the granular material's water content. Diefenderfer et al. (2001) list six detrimental effects of excess water: pumping of fines and durability cracking in rigid pavements, frost-heave and thaw weakening, movement of unbound fines in flexible pavement base and sub base layers, decreased shear strength of unbound materials, and asphalt stripping in flexible pavements. In a recent accelerated load test, Erlingsson (2009) employed a Heavy Vehicle Simulator (HVS) to show that the rate of rutting in all layers of a flexible structure increased with a rise in the groundwater table.

According to the study of De Castro et al., (2022) entitled “A Proposed Design of Drainage System in Phase 3 St. Jude Village City of San Fernando, Pampanga” A drainage system is a channel structure that distributes, transports, and organizes runoff from different sources of precipitation through controlled outflow. Smaller villages may experience floods and rainfall if the sewage system is malfunctioning. The goal of drainage systems is often to divert rainfall and wastewater to a spillway, such as rivers, streams, reservoirs, and coasts. Source control is the first step in managing a drainage system, followed by site control and regional management (Wihaji et al., 2018). Rainwater retention structures are designed to lessen the strain on the primary drainage channels by capturing and discharging surplus surface water runoff that may result in flooding.

In addition, while housing is being built, floods may be managed by maintaining and cleaning irrigation systems. The quick building of urban reservoirs elevates flood levels by up to six times, causing urban flooding. Wide-ranging effects may result, including short-term property loss and harm to public infrastructure. Additionally, urban flooding increases the risk of illness and degrades groundwater supplies.

Based on the study of Agcopra et al., (2023) “An Assessment of the Installed Drainage Systems Situated at Barangay Carmen, Cagayan De Oro City” Drainage assessments provide information about local hydrology and hydraulics that can be used to evaluate drainage conditions under existing or future conditions. The

drainage assessments are a cost-effective way to identify and evaluate potential drainage-related complexities at any location. In addition, drainage assessments are used to identify existing flood threats and to evaluate the need for drainage improvements.

For sustainable development, various options help to improve monitoring and to reduce the impacts of flood damages were elaborated with the assistance of the district departments (PAGASA/DPWH) of the government high-quality information on hazards and potential risks and the widespread dissemination of this information are vital for effective risk and risk reduction. In addition, a better understanding of flood behavior is required, and a more permanent option to reduce the destructive effects of floods is desirable. Some flood reductions include gates preventing the backup of high flood waters, reservoirs, and retention dikes, widening and deepening drainage, retention ponds, and retarding basins, watersheds, and diversion channels. This mitigation reduces the overall risk to some degree, but it is impossible to eliminate it.

The study "Proposed Drainage System in Purok 1, 2, and 3 of Barangay Sta. Tereza 2nd, Lubao, Pampanga" by De Silva et al. (2023) In order to control stormwater runoff and safeguard the neighborhood from issues linked to flooding, the suggested drainage system will be essential. Prioritizing the installation of efficient and sustainable drainage systems is crucial to reducing the risk of floods and standing water damage. Determining the proper infrastructure and capacity to stop flooding and water damage in the area is based on the calculated values for peak

discharge, temporal concentration, and runoff coefficient. It is crucial to remember that the community's active involvement in the proposed drainage system's upkeep and monitoring is essential to its success.

The formula for determining the normal depth of flow is based on the maximum discharge determined by the rational technique. The optimal geometry should be determined by taking into account the most effective cross section. The rectangular canal was the only shape taken into consideration because it is sufficiently large and typical in DPWH drainage design.

The drainage system design's conclusions indicate that the system's dimensions are sufficient to manage the usual rainfall. Even in the event of persistently rainy weather, the drainage system could function. However, this simply takes rainfall data into account. It might not be able to handle all of the water influx when all other considerations are taken into account. Because it is simpler to construct, maintain, and handle water, the researchers suggested a rectangular drainage system. The experts also recommended a rectangle drainage system since it can hold more water because it has a larger area than a circular drainage system. However, when we take into account every other aspect of water influx besides rainfall, these statistics will change.

According to the study of Bartolo et al., (2024) entitled “Run-Off Analysis for a State University: An Input to Drainage System Design and Management Plan for Don Honorio Ventura State University (Main Campus), Pampanga, Philippines”

There are two commonly used methods which arethe Curve Number (CN) Method and the RationalMethod. These are used to create a suitable and effective drainage system design and management strategy. The rational method employs the amount of runoff that a certain type of surface would flow over, whereas the CN method uses the moisture status of soils. Both methods use a rainfall event and catchment area to determine the peak run-off rate. Furthermore, the CN Method can be used on wider regions, whereas the Rational Method is restricted to smaller land plots of roughly 0.8 km^2. Nevertheless, the CN Method is a more thorough analysis that requires more input parameters than the Rational Method, which is more empirical and straightforward and focuses on determining the peak run-off rate where the university is below the 0.8km2 limit.

However, Time of Concentration (Tc) is required to ascertain one of the method's factors, namely the intensity of the rainfall, in order to calculate the peak run-off rate using the Rational Method.

Tc is computed by examining the topography of a certain watershed or catchment area to ascertain the average slope and maximum water travel length of the region. Doing a topographical survey of that particular area will reveal these two parameters. Profile leveling surveys and differential leveling surveys are the two categories of topographical surveying. Drains, highways, fences, and retaining walls are examples of structures that use profile leveling to create elevation variations along a line. It offers a cross-sectional or side view of the earth's surface and is frequently utilized for utilities, streets, and sidewalks. Finding the slope between

locations, trench depths, and other uses are the main goals of profile surveys. Conversely, elevation variations between places are directly measured via differential leveling. It is frequently employed in many different applications, including tidal measurements, GPS waypoint connectivity, and assessing the land's inherent stability.Differential leveling transfers an elevation from one spot to another by using the vertical distance difference between two points.

Synthesis of Review of Related Literature and Studies

The need for efficient and sustainable drainage systems to handle the rising flood hazards brought on by urbanization and climate change is emphasized in both foreign and local literature. In order to increase flood management, water quality, and urban resilience, foreign studies emphasize the significance of creative engineering and nature-based solutions, such as Sustainable Urban Drainage Systems (SuDS), Low Impact Development (LID), and enhanced hydraulic designs.

The majority of the studied literature concurs that enhancing drainage infrastructure necessitates striking a balance between environmental sustainability, technical innovation, and appropriate management. Local gaps still exist in implementation, policy integration, and ongoing monitoring, nevertheless. These results provide a solid foundation for the current investigation, which seeks to provide a drainage solution that is both sensitive to regional circumstances and compliant with international best practices.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter focuses on the research procedures and methods used by the researchers to systematically address the study's particular difficulties. Specifically, the numbers of respondents, surveys, research design, sample and population, research instrument, data gathering, and statistical treatment.

Research Design

This chapter outlines the research methodology, beginning with a detailed description of the procedures followed throughout the study. It highlights key components such as the number of respondents, the sampling technique used, the deployment of surveys, the chosen research design is quantitative, and the specific instruments employed in collecting data, particularly in the context of construction-related research.

Sample and Population

The target population for this research consists of an estimated 80 households residing in Phase 3, Main Road, Barangay FVR, Norzagaray, Bulacan. These households represent a diverse set of family structures, economic backgrounds, and their experiences throughout living in the said area. From this total population, a sample of 100 individuals aged 18 to 50 years old respondents will be selected.

This study used a purposive sampling technique in identifying the samples of this study. Purposive sampling aims to find people in the population who are most likely to have specific traits or experience (and are willing to share them). In this approach, researchers can narrow their population to a relatively small sample size and choose the people or situation that fit in the study.

Research Instrument

We will present the survey questions along with a description of the type questionnaire we used. We will describe the data collection tools, which include the questionnaires that we developed for our study participants.

We will distribute printed questionnaires containing 15-20 questions to specific residents of Phase 3 main road barangay FVR, Norzagaray for our data collection process. The respondents will complete these forms face-to-face while we conduct personal interviews to address any questions that arise during the process.

For preparation, we have allocated a time frame of 1 week for survey preparation, and we will conduct interviews on different days to handle scheduling effectively.

Design

The primary research tool used is CAD (Computer-Aided Design) software, which enables the creation of detailed designs for the rigid road pavement and covered channel drainage system. This tool allows for precise visualization, measurement, and modification of the physical layout, serving as the foundation for both construction planning and cost estimation.

Cost Estimation

Excel Sheet serves as a quantitative research instrument to convert the physical designs created in CAD software into measurable budgetary data. It allows the researchers to systematically quantify the costs associated with materials, labor, equipment, and other project components.

Data Gathering

The researchers employed a questionnaire as the main research tool to gather the data required for the purpose of the study. A group of researchers validated this questionnaire in order to guarantee its content validity and reliability. After it was completed, the questionnaire was given to the intended respondents, who were chosen with care according to the research criteria.

The respondents received an explanation of the study's objectives and a guarantee that any information they submitted would be kept completely private and used exclusively for research purposes. Once the forms were collected and thoroughly examined, the answers were tallied and arranged in tabular form, presenting all of the responses for each of the questions.

Statistical Treatment

The following statistical procedures were used to interpret the data gathered from the respondents of the study. Furthermore, the researchers selected these statistical tools as they were considered most suitable for addressing the objectives of the study.

$$P=\frac{F}{N}(100)$$

Where:

P = Percentage

F = Frequency for each category

N = Total number of respondents

Discharge and Flow rate formula

Q = C i A *(equation 1)*

Q = V A *(equation 2)*

Where:

Q = Discharge/Flow rate (cu.m/s)

C = Runoff Coefficient

i = Average rainfall intensity (mm/hr)

A = Catchment area (sq.m)

V = Average Velocity (m/s)

Manning's Equation

$$V = \frac{R^{\frac{2}{3}} S^{\frac{1}{2}}}{n}$$

(equation 3)

Where:

V = Average Velocity (m/s)

n = Manning Roughness Coefficient

S = Slope of the Channel (m/m)

R = Hydraulic Radius (m)

Hydraulic Radius (R)

$$\mathbf{R} = \frac{\boldsymbol{Cross\ Sectional\ Area\ of\ Flow\ (A)}}{\boldsymbol{Wetted\ Perimeter\ (P)}}$$

(equation 4)

Bernoulli's Principle (Orifice Flow)

- For Grated or Slotted inlet

$$\mathbf{Qi = Cd\ Ao}\sqrt{\mathbf{2gh}} \quad \textit{(equation 5)}$$

Where:

Qi = Flow through inlet (cu.m/s)

Cd = Discharge Coefficient

A*o* = Total open area of grate (sq.m)

h = Water depth above grate (m)

g = acceleration from gravity (9.81 m/s^2)

Thank you for participating in this survey. Your responses will help assess our research titled "DESIGN OF ROAD RIGID PAVEMENT AND COVERED CHANNEL DRAINAGE SYSTEM FOR FLOOD MITIGATION IN PHASE 3, MAIN ROAD, BRGY. FVR NORZAGARAY, BULACAN." All responses are anonymous and will be used for research purposes only. The survey should take about 10-15 minutes to complete.

General Instruction: Put a check mark (✔) on the box that corresponds to your answer.

Gender: ☐ Male ☐ Female

Age: ☐ 18–24 ☐ 25–34 ☐ 35–44 ☐ 45–50 ☐ 50 or older

Residing years: ☐ Less than 1 year ☐ 1–5 years ☐ 6–9 years ☐ 10 years Above

Part I: IMPACT OF POOR DRAINAGE SYSTEM ON DAILY LIFE (***Current Situation Assessmen***t)

5- Always 4- Often 3-Sometimes 2-Rarely 1-Never

Question	5	4	3	2	1
1. How often do you experience difficulty walking on flooded sections of the main road?					
2. How often do floods lead to accidents dangerous situations for drivers (e.g., slipping, vehicle breakdown)					
3. How often do you notice that flooding contaminates the safety of your household water sources? (e.g., deep wells)?					
4. How often do you observe that uncollected garbage and waste make flooding worse in your area?					
5. How often does the floodwater entering your home cause damage to personal property and other belongings?					
6. Do you feel unsafe walking on the main road during heavy rain because of flooded areas?					
7. Have you ever been worried about water-borne diseases (e.g., diarrhea, typhoid) due to contaminated floodwater.					
8. The lack of a proper drainage system makes the area attract pests like mosquitoes and rats because of collected rainwater with accumulated waste.					

Part II: PERCEIVED BENEFITS OF PROPOSED PROJECT ***(Road Pavement and Drainage Construction)***

5- Strongly Agree 4-Agree 3-Neutral 2-Disagree 1-Strongly Disagree

Question	5	4	3	2	1
1. Do you think the new road will improve your safety during the rainy season?					
2. Will the new drainage system reduce flooding in your area?					
3. Do you believe the new road and drainage system will improve mobility for vehicles?					
4. Do you think the new system will enhance the overall comfort, convenience, and quality of life of the residents?					
5. For you, will the improvements increase the overall satisfaction for residents and drivers?					
6. The new drainage system will improve overall sanitation and hygiene in the community.					
7. The new drainage system will help prevent the spread of diseases related to stock floodwater.					
8. Do you believe this new infrastructure is a necessary and beneficial investment for the entire community.					